Uses and limits of thermal indices: the case of Sahel

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Objectives & key points

Tropical regions: warm environment where temperature extremes generate health impacts. Mean basic state is already warm and rather close to some physiological thresholds (example : 200-250 days with Tx > 35°C).

The study is threefold:

1. Select the heat index (HI) the most relevant to the tropical dry area of West Africa.

2. Test the modified HI of Steadman (1979) using 2 declinations of it's definition.

3. Characterize and analyse heat waves (HWs) in West Africa, particularly in the Sahel (13°N- 18°N; 16°W-30°E).

Setting:

Data and methods

Daily temperature observational data

Minimal temperature (Tmin), maximal temperature (Tmax) and mean temperature (Tmean) from Global Summary of the Day (GSOD) synoptic observations during Januany-December 1973-2014.

Network of 145 stations (Fig. 1).

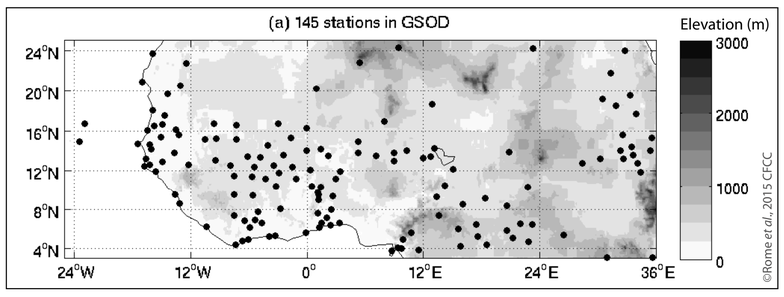

Figure 1. Meteorological data network available in West Africa: location of the 145 stations available in GSOD having at least 3650 daily entries in the 1973-2013 period.

Calculation of the Sahel Heat Wave index (HW$_{iSahel}$)

The calculation of HW is derived from Steadman's Heat Index (HI) formula (1979, Equation 1, Fig. 2) amended (see § HW detection).

$$HI = c1 + c2\,T + c3\,R + c4\,T\,R + c5\,T2 + c6\,R2 + c7\,T2R + c8\,TR2 + c9\,T2R2 \qquad [Eq.\ 1]$$

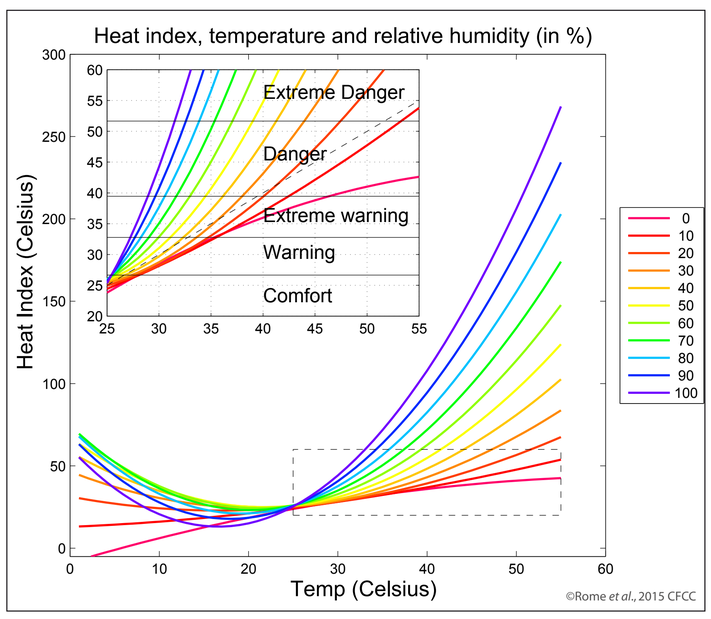

Figure 2. Approximation of the Heat Index converted to Celsius (modified from Steadman, 1979). Colors indicate the level of HI, from comfort to extreme danger.

Where:

HI= heat index (in degrees Fahrenheit); T= ambient (in degrees Fahrenheit); R= relative humidity (percentage value between 0 and 100);

c1 = -42.379; c2 = 2.04901523;
c3 = 10.14333127; c4= -0.22475541;
c5 = -6.83783 *10-3; c6 = -5.481717 *10-2;
c7 = 1.22874 *10-3; c8 = 8.5282 *10-4;
c9 = -1.99 *10-6.

HW detection and definition for the Sahel

In dry tropical zone like the Sahel, a heat wave is detected when the heat index of the day (HI$_{max}$) and of the night (HI$_{min}$) exceeds the 90th percentile (T90) for at least 3.5 consecutive days (7 overruns).
The T90 is calculated with 2 declinations:

1) On 5-day moving window average. This calculation removes seasonality and detects HW whatever the time of year.

2) Over all days of the year. This calculation can identify the strongest heat stress potentially impacting human health, one of the ACASIS program goal.

Results

Hierarchical clustering (CHA) of mean annual temperature

A classification of stations according to their annual thermal regime (Fig. 3)

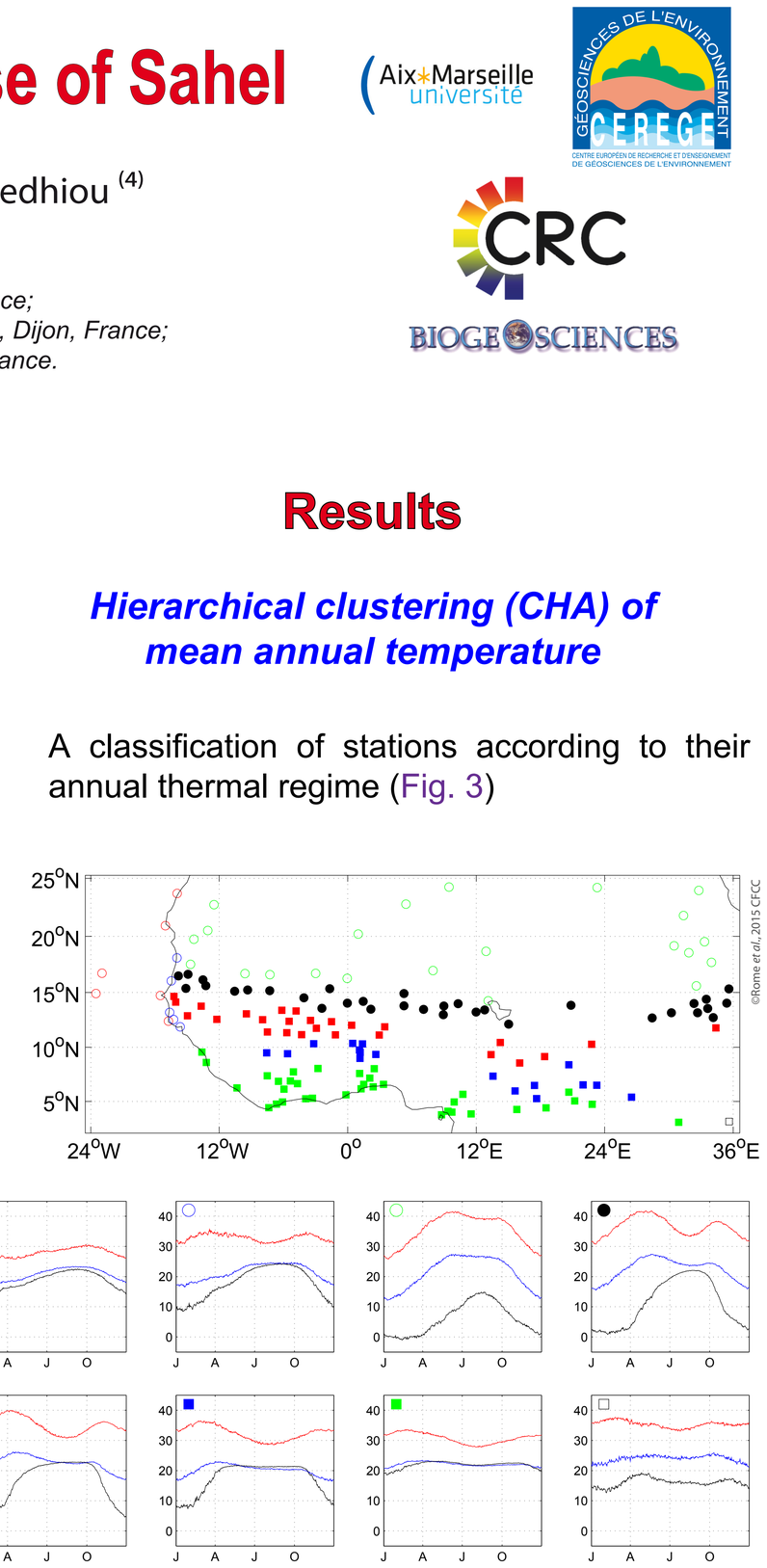

Figure 3. Spatial and temporal variation of temperature (in Celsius) in Tropical Africa north of Equator (Tn in blue, Tx in red and dew point in black) obtained by hierarchical clustering (CHA) of mean annual cycle computed on 1973-2014 period.The curves are the spatial average (except for the first cluster which includes a single station – Nouakchott-) of the stations assigned to a given cluster.

Spatial and temporal extent of HW in West Africa

HW$_{iSahel}$ (modified HI of Steadman, 1979), using 2 T90p thresholds (Fig. 4).

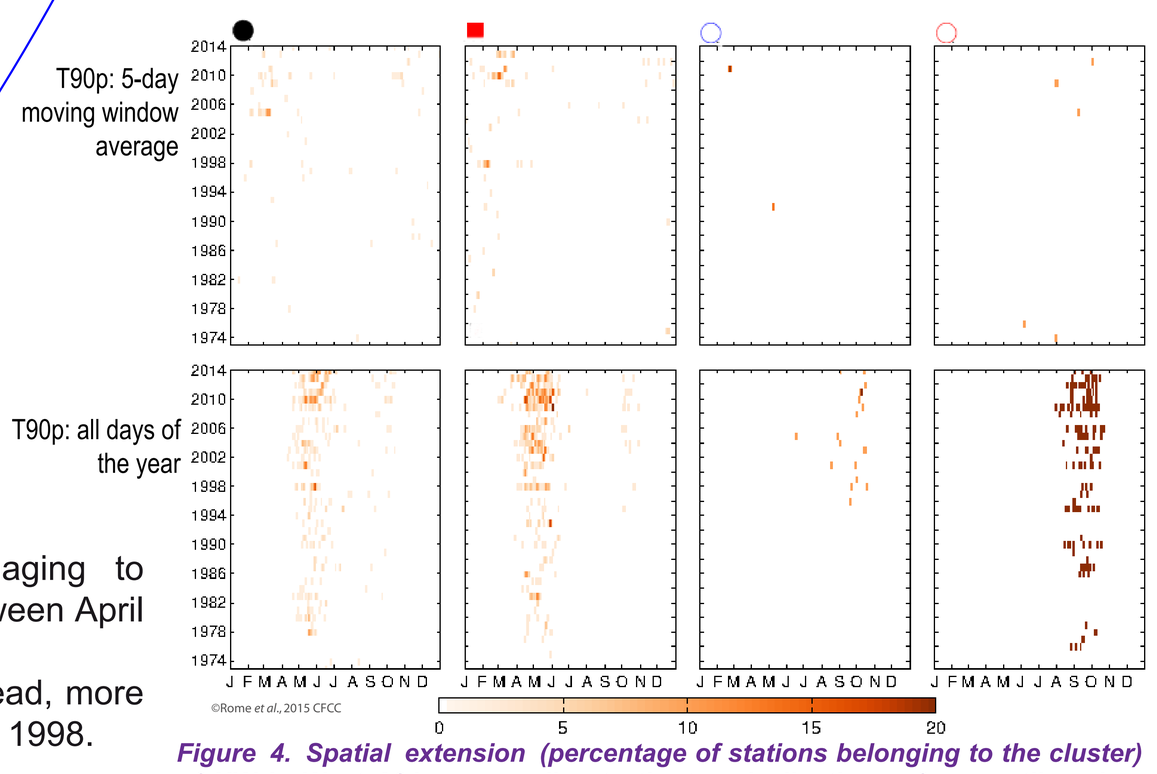

Figure 4. Spatial extension (percentage of stations belonging to the cluster) of HW in West Africa, according to the two declinations of percentile calculation (top: 5-day moving window average; bottom: all days - see § definition). Green, blue and black squares correspond to the clusters shown in figure 3.

The Sahel HWs damaging to health occur mostly between April and July (Fig. 4 bottom).
They are more widespread, more and more frequent since 1998.

HWs are more severe during the dry season (Fig. 5).

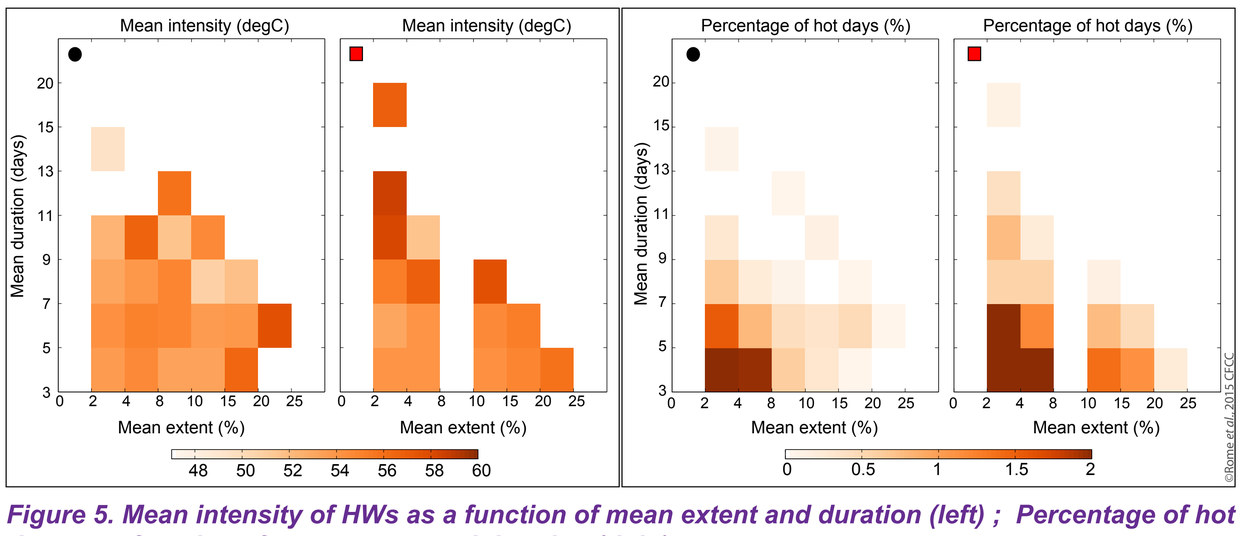

Figure 5. Mean intensity of HWs as a function of mean extent and duration (left) ; Percentage of hot days as a function of mean extent and duration (right).

Short (3-days) and weekly extended (2-8 %) HWs occur frequently but have weak intensities (less than 54 ° C).

HWs with higher intensity (larger than 54 ° C) last longer (more than 9 days) and/or cover large areas (larger than 10 %), depending on the domain.

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